Acceleration of EUV Resist Development with EB Tool

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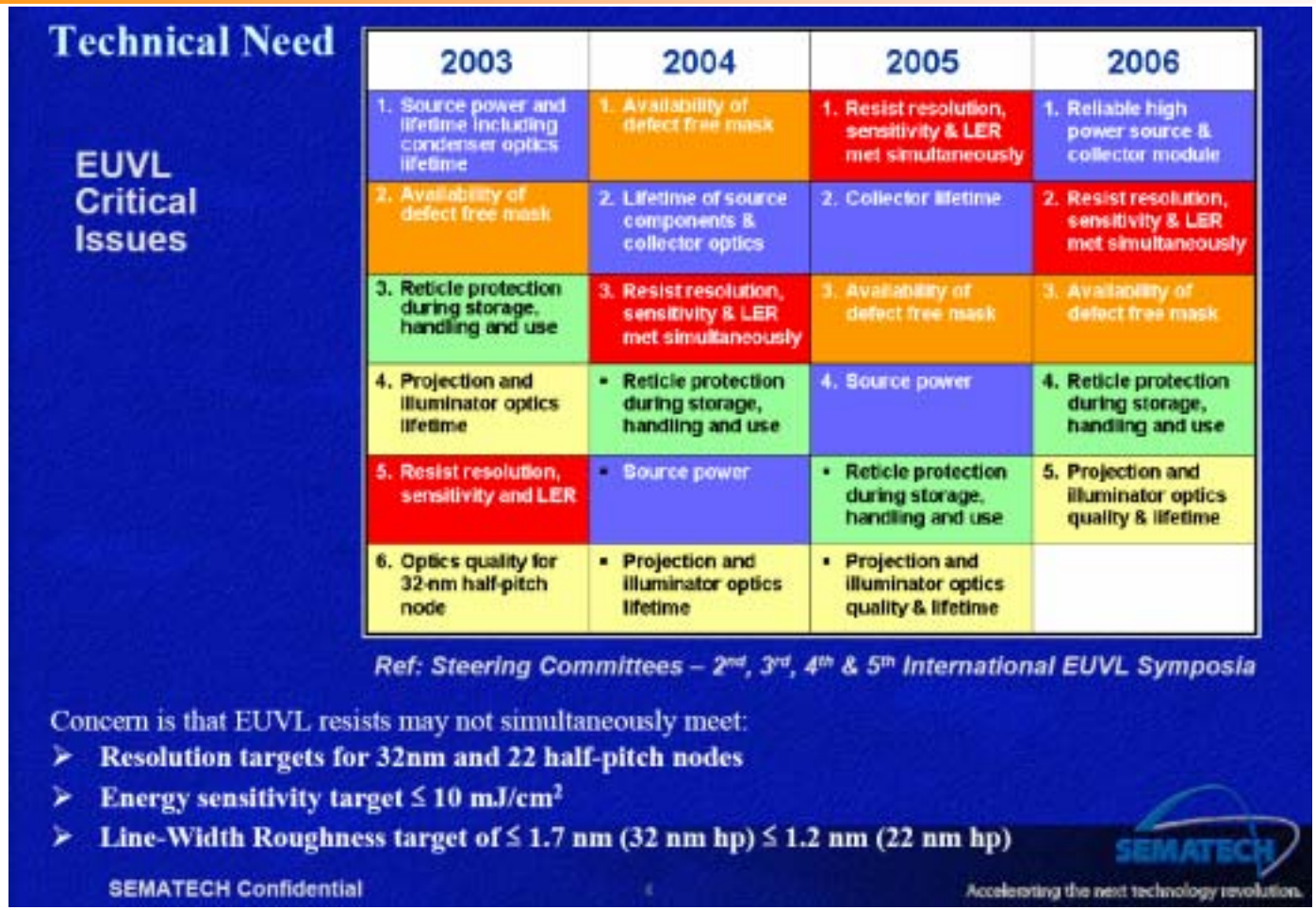
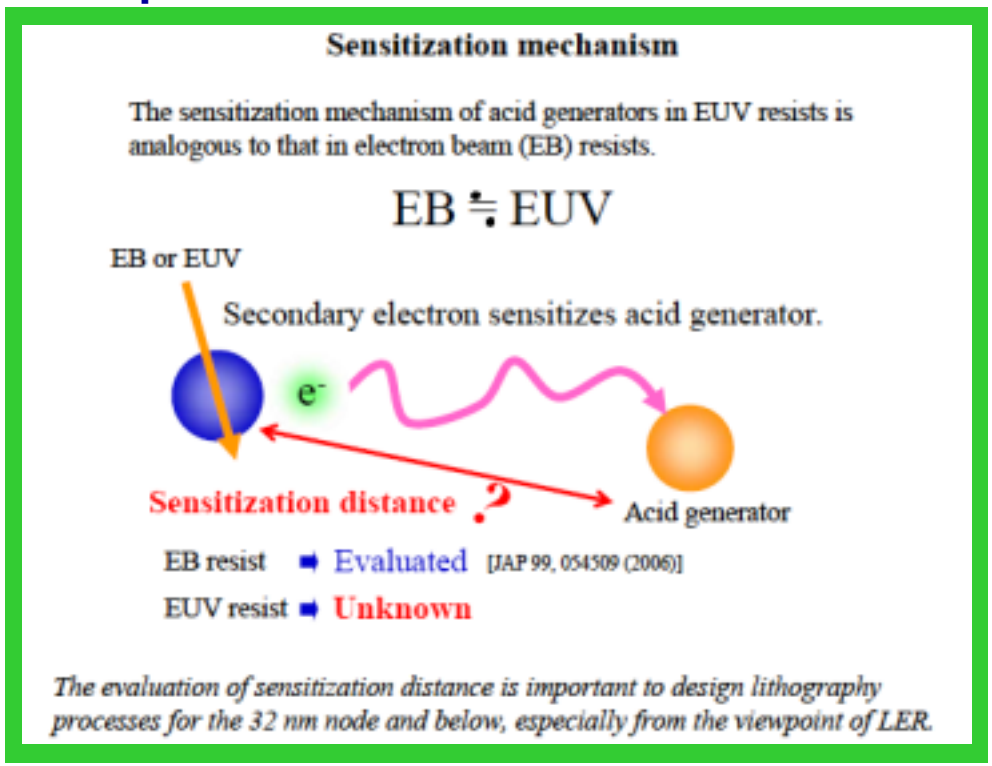
EUV Lithography Critical Issues



- It has been mentioned by SEMATECH that EUV resist may not meet the resolution (hp 32nm & beyond), sensitivity (less 10mJ/cm^2@180W source power) and LWR (1.7nm@hp32nm).
- Outgas issue from the resist upon EUV irradiation is also a critical concern for a stable process establishment.

Motivation

- There are currently a limited number of EUV exposure tools in existence worldwide such that the opportunity for exposure is quite limited.
- It is important to establish a correlation between the EUV tool and other exposure tools for resist lithographic performance to accelerate the EUV resist development .



T.Kozawa , et al., EIPBN 2007

Investigation of Energy Transparency of EB and EUV

EB

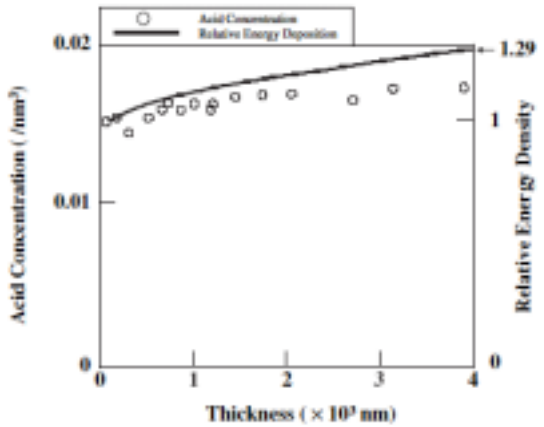


Fig. 4. Dependences of acid concentration (solid circles) and average absorbed energy density (solid line) on resist thickness. The average absorbed energy shown here was normalized to that at the acid concentration at 65 nm for comparison. The dependence of the absorbed energy density was calculated by SELID.

T.Shigaki , et al. JJAP Vol45 (2006) 5445

EUV

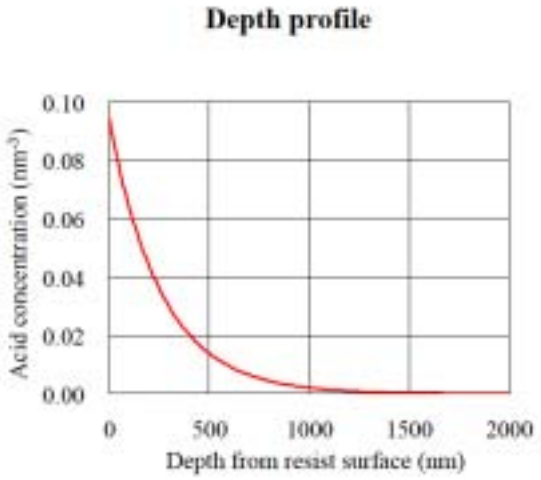


Fig. Depth profile of acid concentration (The number of acid molecules per unit volume). The exposure dose is 10 mJ cm^{-2}.

T.Kozawa et al., JVSTB. Vol 24 (2006) L27

EB: The depth of resist film has little to no effect on Acid generation
EUV: The depth of resist film has no effect on Acid generation

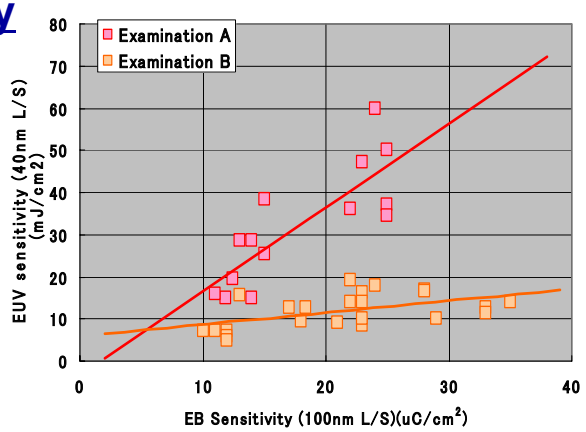
EB and EUV
- **In general, the acid generation mechanism are simliar**
- **Energy transparency is different**

Correlation of lithographic performance between EB and EUV

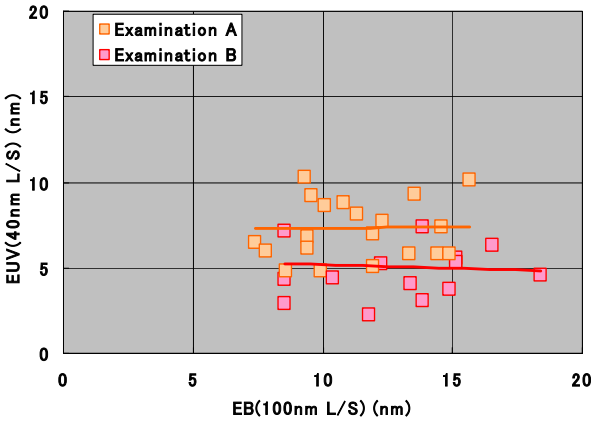
Previous Work at TOK

Correlate between EB and EUV: Sensitivity and Resolution

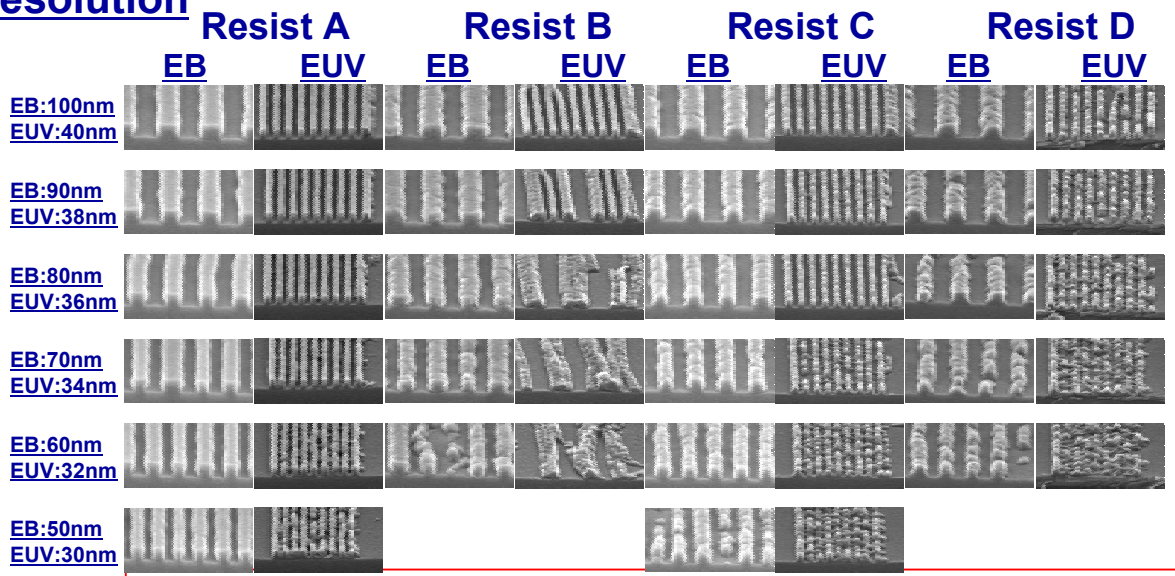
Sensitivity



LWR



Resolution

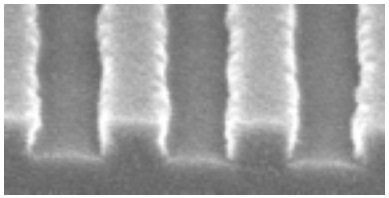
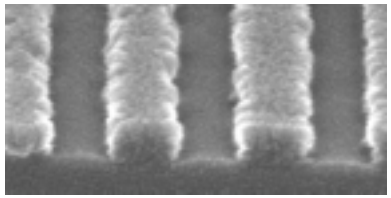
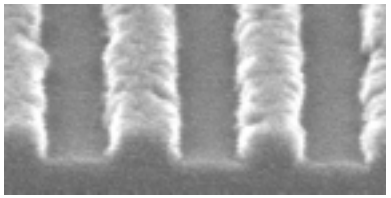
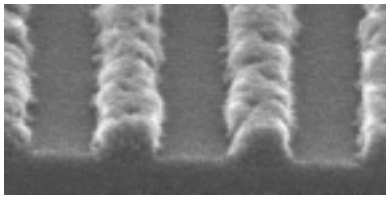
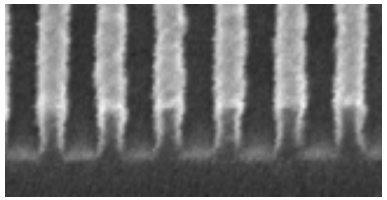
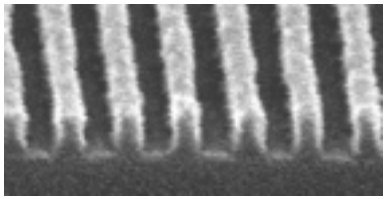
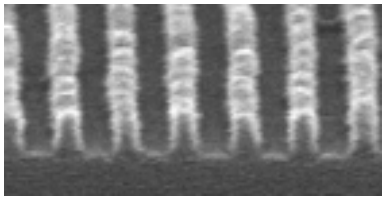
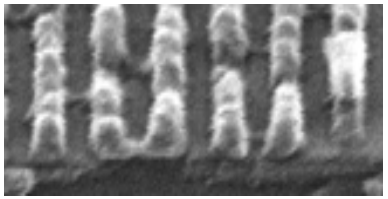


Process conditions
Film thickness; 100nm(EB) / 60nm(EUV)
PAB; 110℃ for 90s
Exposure; HL800D (70kV) (EB) / MET@LBNL-MET (EUV)
PEB; 100℃ for 90s
Development; 0.26 N TMAH for 60s puddle

Sensitivity - good correlation between EB and EUV
Resolution - correlation not so bad, but pattern collapse could not be prevented
LWR - no relationship identified

Previous Work at TOK

Correlate between EB and EUV: Pattern Profile

	Resist A	Resist B	Resist C	Resist D
EB FT:60nm CD:100nm				
EUV FT:60nm CD:40nm				

Sensitivity: High correlation with EB and EUV when exposure takes place on the same day
Resolution: Moderate correlation, but pattern collapse can confuse our judgment
LWR: No relationship from previous data
Profile: Similar tendency observed for pattern profile, EUV profile shows higher thickness loss than EB exposure

These results correlate with past experiments of other presentations

Process conditions
Film thickness; 60nm(EB) / 60nm(EUV)
PAB; 110℃ for 90s
Exposure; HL800D (70kV) (EB) / MET@LBNL-MET (EUV)
PEB; 100℃ for 90s
Development; 0.26 N TMAH for 60s puddle

Difference between EB and EUV

	EB (TOK)	EUV (Berkeley et at all)
Light source	Electron beam	Soft X-Ray
Energy	70keV	0.0925keV
Energy transparency	High	Low
Exposure system	Drawing	Mask
Flare	Non / Low	High（>7～10%)
Vacuum level	10^{-5}	10^{-8}

We focusing these difference

There are effective for

- ■Pattern profile
- ■LWR
- ■Sensitivity
- ■Resolution

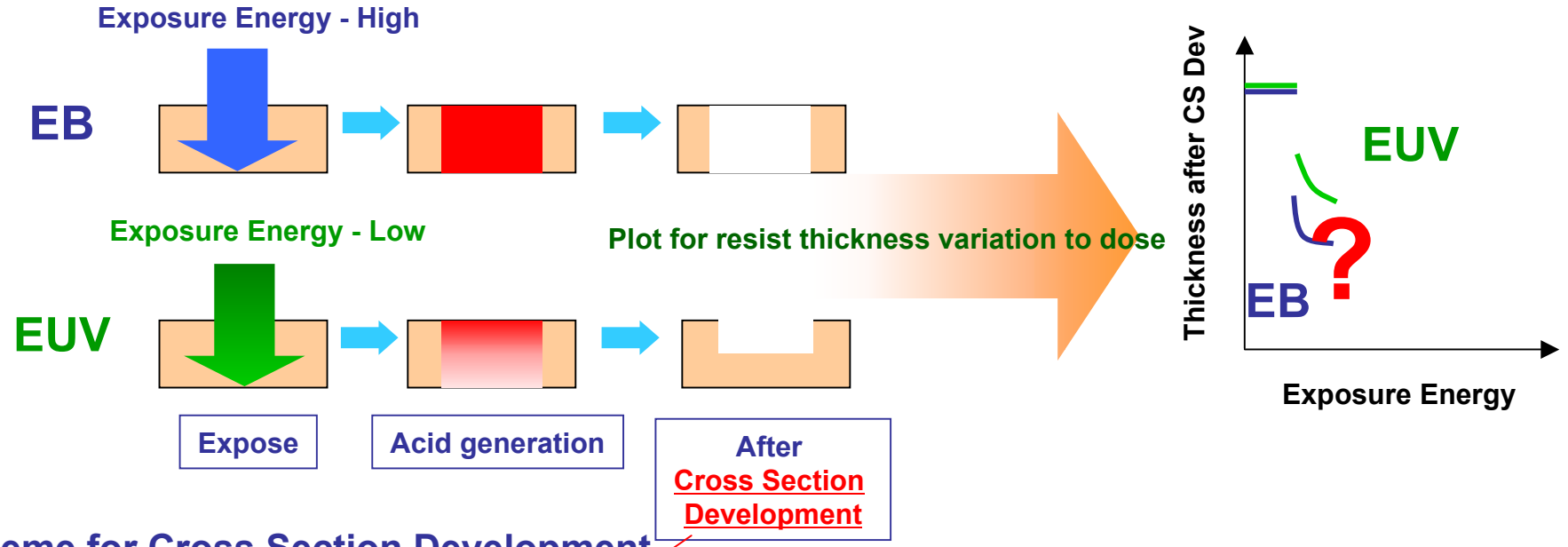
etc

Next step: Investigation of these differences

Cross section development

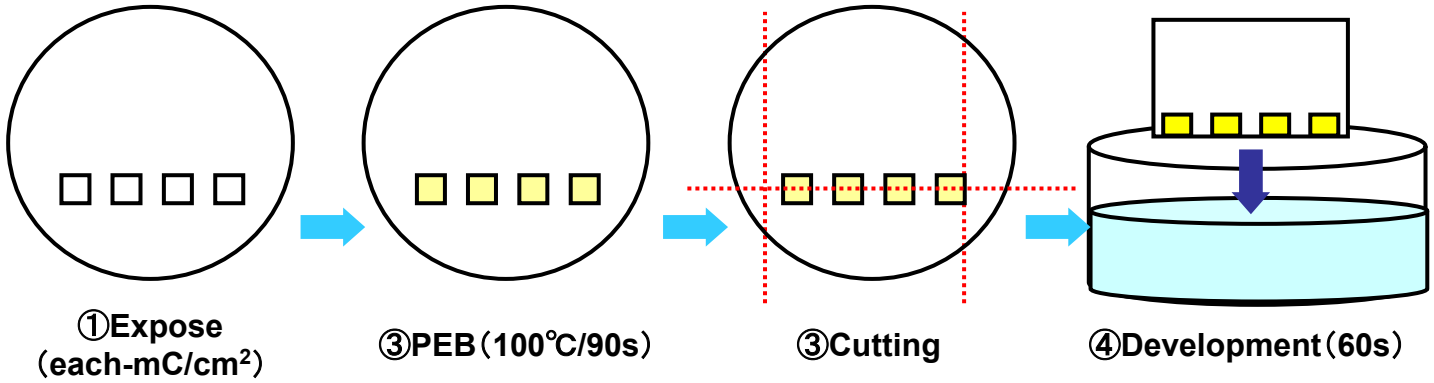
Cross Section Development

Objective: Investigation of energy loss within resist film for both light source

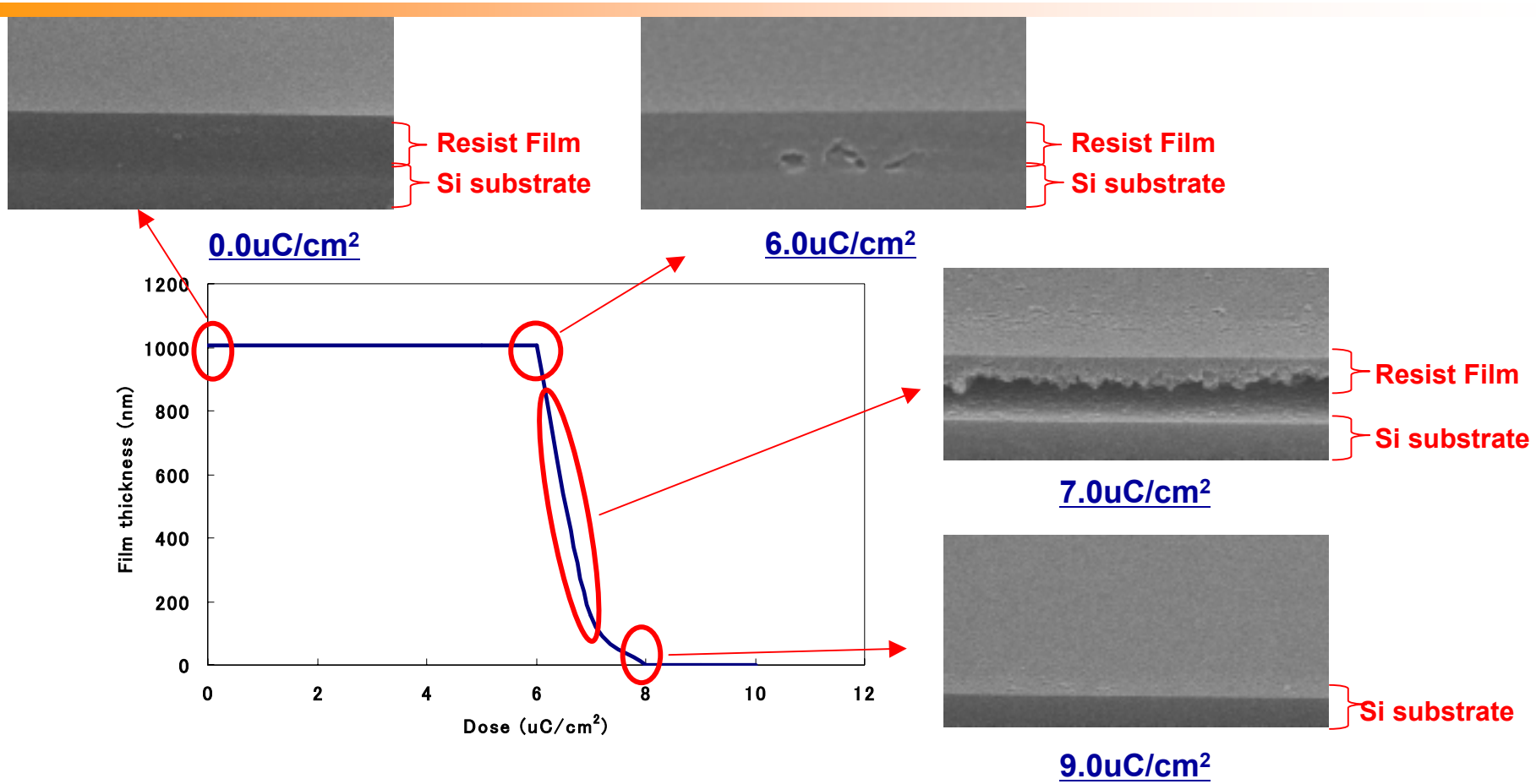


Scheme for Cross Section Development

Expect for effect of resist surface non de-protecting layer



Cross Section Development Test @ EB

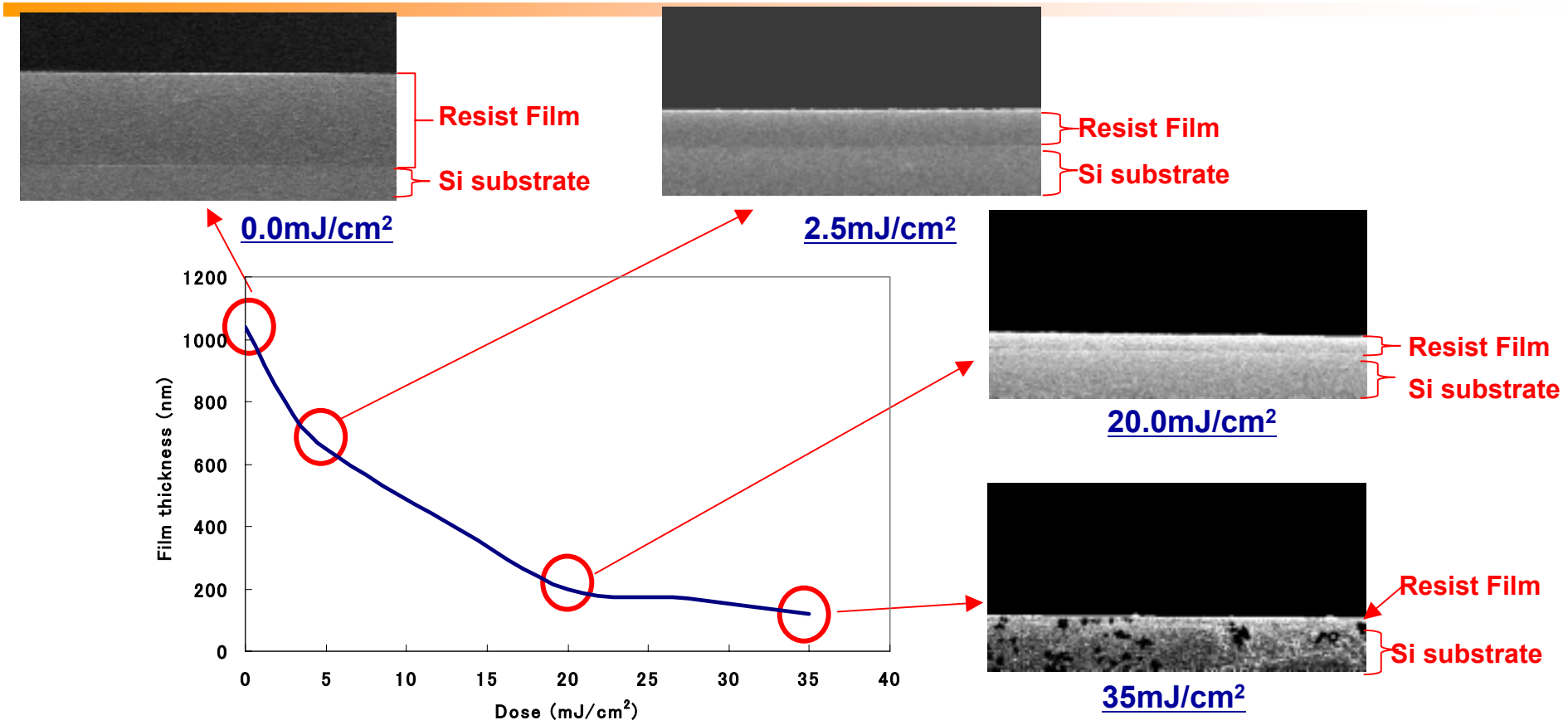


EB shows that the first de-protection point is the resist-substrate surface from this evaluation

Process conditions

Film thickness;	1000nm
PAB;	110℃ for 90s
Exposure;	HL800D (70kV)
PEB;	100℃ for 90s
Development;	NMD-3 2.38% of 0.26 N TMAH for 60s Dip

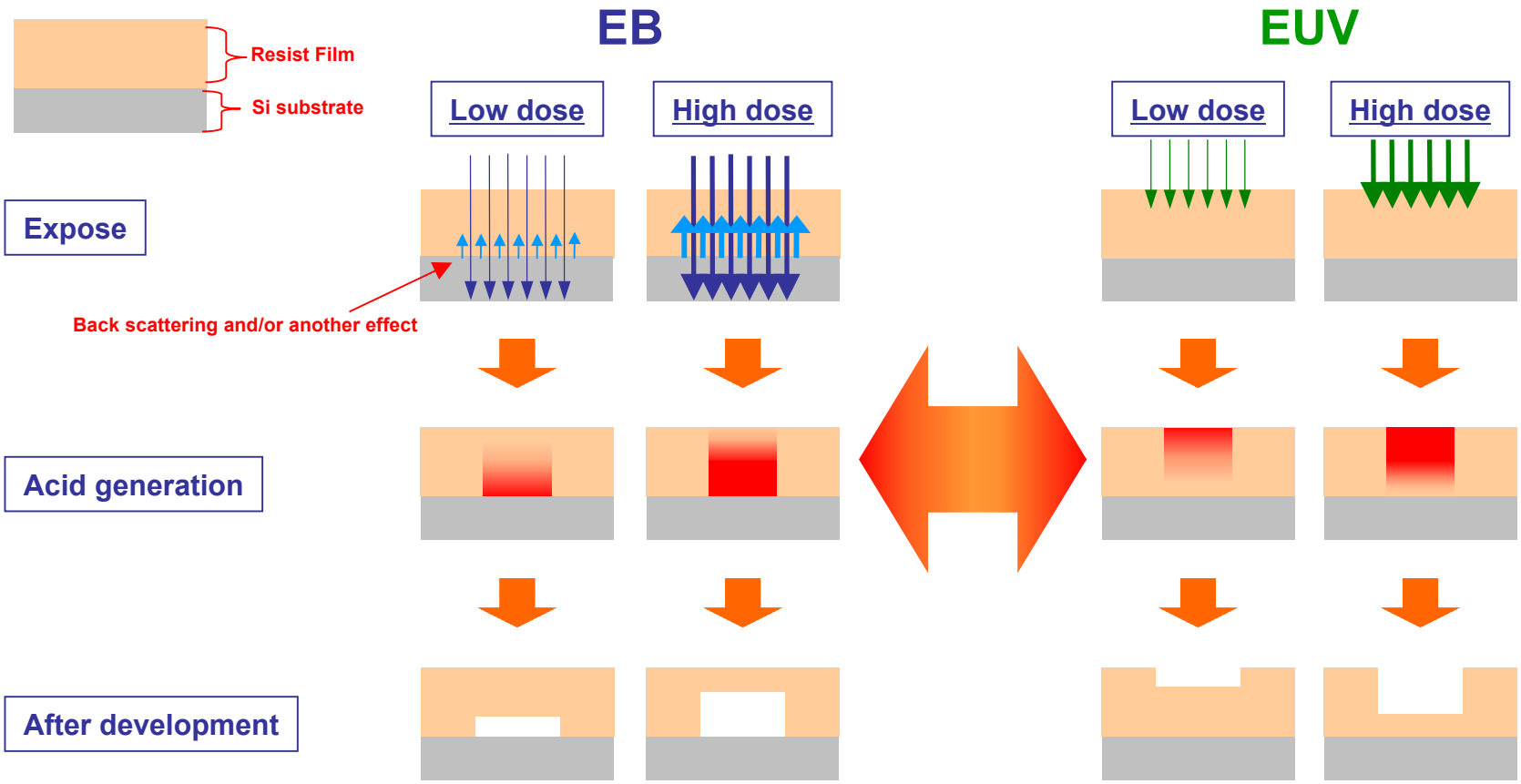
Cross Section Development Test @ EUV



EUV exposure show that the first de-protection point is at the resist surface from this evaluation

Process conditions
Film thickness; 1000nm
PAB; 110℃ for 90s
Exposure; SFET(Selete)
PEB; 100℃ for 90s
Development; NMD-3 2.38% of 0.26 N TMAH for 60s Dip

Short Summary of Cross Section Development



From this supposition, EB can not achieve the same profile as the EUV radiation

If we want to simulate that condition, we will have to try …

Simulate photo effect => Next Step: Investigation of EB and KrF Double Exposure

Cancel the back scattering effect :

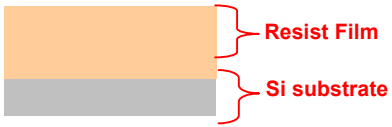
Double Exposure Test with EB and KrF-1

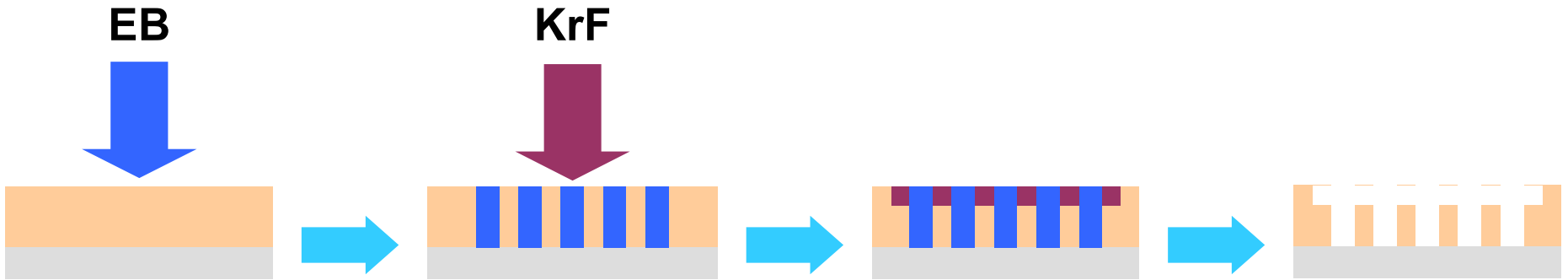
Process Condition and Scheme

Objective: Investigation into simulating EUV photo effect

Process conditions

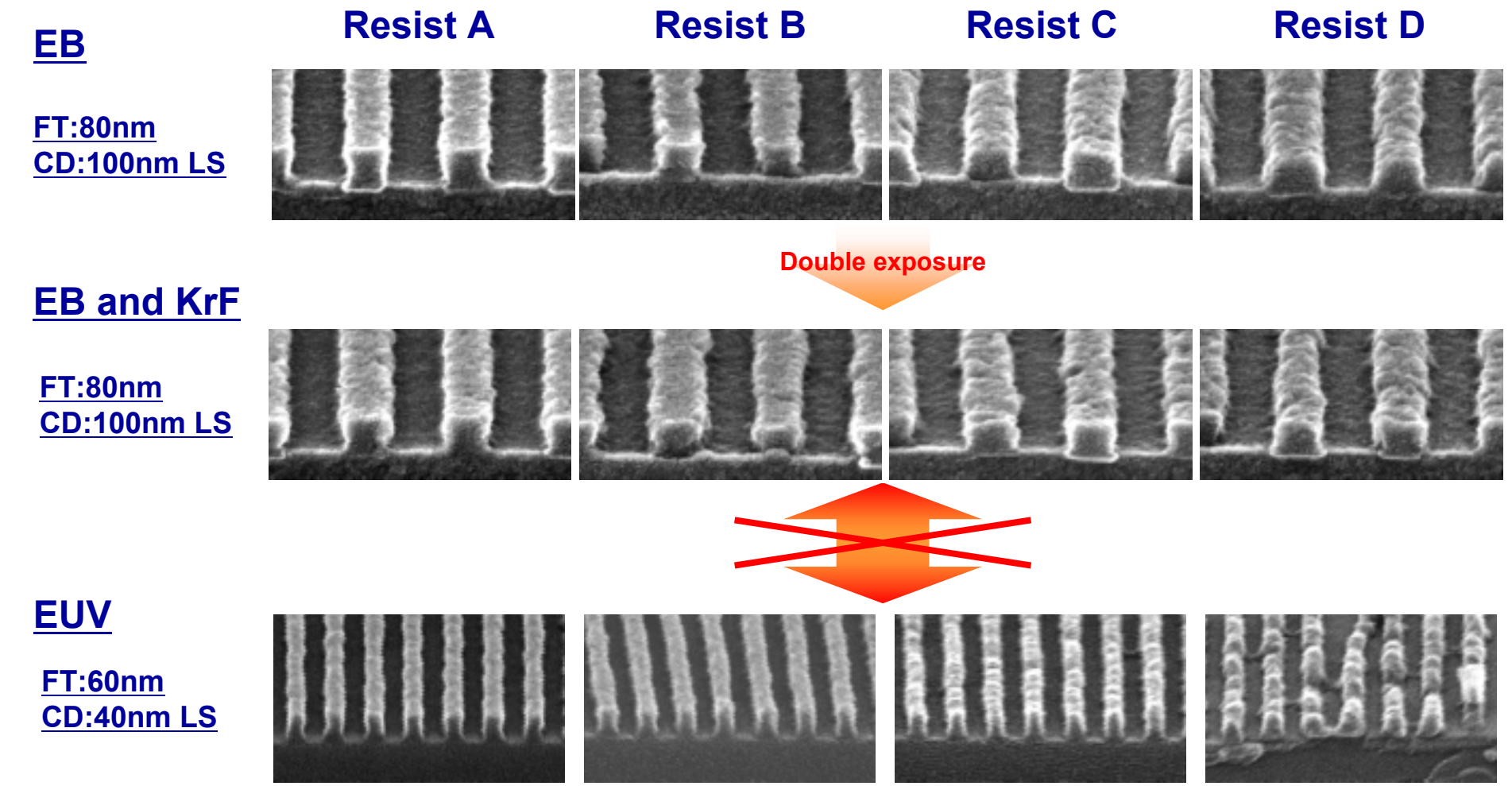
PAB;	110℃ for 90s
Exposure;	HL800D (70kV)(EB) / NSR-S203B (KrF) (NA0.55 σ :0.68)/LBNL-MET(EUV) (Y-monopole)
PEB;	100℃ for 90s
Development;	NMD-3 2.38% of 0.26 N TMAH for 60s puddle





Double Exposure Test with EB and KrF-2

Pattern Profile Correlation between Three Conditions



EB and KrF Double exposure showed pattern thickness loss, but these profile does not correlate with EUV results.

Short Summary of Double Exposure Test

- EB and KrF double exposure had low correlation with EUV results
- We believe that this is a result of:
  - ✓ A difference in acid generation mechanism with KrF and EUV exposure, therefore the samples did not have the same effect on pattern profile formation
  - ✓ A difference of energy (EB-high), especially at the substrate surface, such that the bottom profile is dissimilar from the EUV results

This test processing could not correlate to EUV result

We can not attain the same pattern profile between EB and EUV

Summary

- We considered the difference in energy transparency between EB and EUV affecting the acid generation amount in the resist film for the cause of low correlation of pattern profile.
  - ✓ EB has stronger energy transparency than that of the EUV radiation and showed de-protection initiating at the substrate surface. The pattern profile has a tendency for T-top profile.
  - ✓ EUV has weaker energy transparency than EB, and showed de-protection starting from the resist surface. The pattern profile resulted in a thickness loss.
- We could not correlate LWR between EB and EUV at this time because similar profiles of EUV radiation were not obtained using the EB and KrF double exposure method.
- We can attain high correlate of sensitivity and resolution between EB and EUV, but not the same with LWR. Therefore, we will continue to investigate for other innovative methods using other equipment settings.

Acknowledgments

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